SPENCEVILLE MINE CLOSURE

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ABSTRACT

Spenceville Mine is an abandoned copper mine located in the Sierra Nevada foothills of California. The mine was operated intermittently from the 1880's until 1918. The site was covered with mine tailings and overburden materials. In addition, the central portion of the site was occupied by a flooded open pit, which contained approximately 6 million gallons of acidic water with a pH averaging 2.5. The U.S Army owned the site from 1941 to 1962, at which time it was transferred to the California Department of Fish and Game (DFG) with the creation of the Spenceville Wildlife Refuge.

In 2000 the DFG developed a mine closure plan that addressed the following: (1) closure objectives; (2) geochemical and geotechnical characterization of the water and mine waste; (3) alternative remedial approaches for treating the mine water, disposing of the mine waste, and filling the pit; (4) evaluation of options in terms of technical and economic feasibility, regulatory compliance and environmental impacts; (5) preliminary designs and detailed costs estimates for two closure options; and (6) selection of a preferred closure plan based on how well each option met the closure objectives.

The closure plan was approved by the regulatory agencies in early 2001, and mine closure activities began in April 2001. In subsequent months a water treatment plant was constructed and used to treat the pit water. The treated water was then applied to land in the vicinity of the site. The mine waste was excavated, treated with lime, and placed in the dewatered pit. A layer of borrow soil was placed as cover over the entire site, and a mine impacted stream was restored to its original channel. In addition to these tasks, closure activities had to address the potential for unexploded ordnances, reclamation of shafts and tunnels in the dewatered pit, and documentation of cultural resources.

As of early 2002, site revegetation, erosion protection, water quality monitoring, and preparation of final reports are ongoing.

INTRODUCTION

Site Location

The Spenceville Mine site is located within the California Department of Fish and Game's (DFG) Spenceville Wildlife Refuge in the foothills of the Sierra Nevada Mountain range, about 20 miles southwest of Grass Valley, in Nevada County. California. The mine site is east of Beale Air Force Base.

Site History

Opened in 1863, the mine operated as the Well Lode Copper Mine from 1863 through 1865 and closed shortly after the Civil War ended. In 1872 Mr. Robert Skinner bought the claim for the San Francisco Mining Company and made $15,000 worth of upgrades. In 1877 Mr. Skinner purchased the Grass Valley Copper Mines that butted up to the western margin of the San Francisco Mining Company's claim and shared the ore body. This purchase required $100,000 in upgrades and the mines became the San Francisco Copper Mine and Reduction Works. In August of 1880 a head frame toppled into a vertical shaft. No fatalities occurred but the cost of clearing the shaft was extensive; in December of that year preparation began to operate as an open cut. Eight years later the mine closed. From 1888 through 1897 the Imperial Paint Company and Copper Works leached the tailings for copper cement and also used them as a pigment in the manufacture of Spenceville Red/Venetian Red paint. The paint, enormously popular to begin with (Gold Medal in SF 1894 Winter Exposition) ended in infamy sometime around 1896/97 when it was discovered that the paint corroded structural nails and barns were beginning to collapse. In 1897 the Spence Mineral Company purchased the mine proper to manufacture sulfuric acid. Between 1915 and 1917 a fire razed the mine properties and all work there ceased for good. An artist's rendition of the Spenceville Mine circa the 1880's is shown in Figure 1.

Figure 1 - Spenceville Mine circa 1880

The mine site has been abandoned since about 1918. The town of Spenceville, east of the mine site, continued to survive on agriculture up to 1941, when the military acquired the property and used the site as a training ground. The town was made into a mock German town where Army recruits trained in preparation for combat duty in Europe. In 1962 the Spenceville Wildlife Refuge was created via a land transfer to the DFG. The Spenceville Mine site and old town of Spenceville are within the Spenceville Wildlife Refuge boundaries. In April 1987, the California Regional Water Quality Control Board (RWQCB), Central Valley Region, asserted regulatory jurisdiction over the site by notifying DFG that the mine was regulated under the Toxic Pits Cleanup Act (TPCA) of 1984. TPCA required that all surface impoundments containing hazardous wastes be closed or modified so they were no longer hazards.

Site Description

The Spenceville Mine site area encompasses approximately 10 acres bounded on the east and south by Little Dry Creek and Dry Creek, respectively. The mine site is located at altitudes ranging from 300 to 500 feet. In the central portion of the mine site was a lake created in a flooded open pit (Photo 1). The lake contained approximately 6 million gallons of acidic water (pH ~ 2.5). The pool's surface area was approximately one-half acre, and the maximum depth of the lake was about 60 to 70 feet. Surrounding the pit on the west and north were piles of waste rock and roasted ore waste that were deposited on the side of a hill (Photo 2). Little Dry Creek flows south and is approximately 80 feet southeast of the mine pit. It joins Dry Creek approximately 400 feet south of the mine pit.

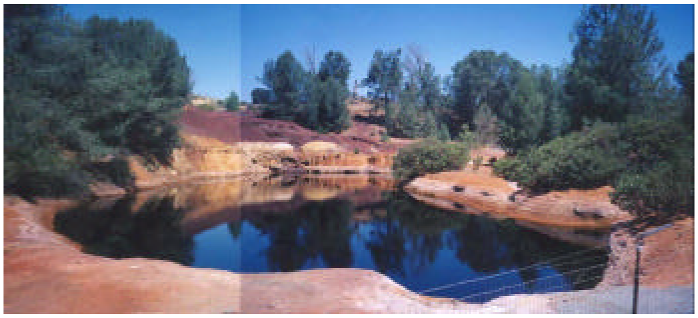

Photo 1 - Spenceville Mine pit

Photo 2 - Mine waste

The pit water had elevated concentrations of sulfate, iron, copper and zinc. Periodic surface water runoff and ground water seepage, from the mine waste material and the open pit lake, discharged low pH waters that were high in copper, zinc, iron and aluminum to adjacent Little Dry Creek (Photo 3). The concentration of copper and zinc in the discharge was sufficient to be detrimental to aquatic habitat. In addition, the proximity of the acidic open pit lake to a public access road created a public safety hazard.

CLOSURE PLAN

A Mine Site Characterization/Closure Plan for the Spenceville Mine was completed by DFG in July 2000. The objectives of the closure plan were to clean up the mine site, treat and dispose of the open pit water, fill the pit, and implement grading, drainage, capping and revegetation measures to leave the site in a condition that minimizes the potential for further impacts to surface and groundwater quality. In preparing the closure plan, geochemical and geotechnical characterization studies of the water and

Photo 3 - Little Dry Creek adjacent to mine

waste materials were performed to fill data gaps that existed in previous work performed by others at this site.

After data acquisition and evaluation, alternative remedial approaches were developed for treating the mine water, disposing of the mine waste, and filling the pit. The various closure alternatives were evaluated in terms of technical and economic feasibility, regulatory compliance and environmental impacts. Based on coarse screening of the possible reclamation alternatives, two main alternatives for closure of the mine site were proposed for fine screening. Preliminary designs and detailed cost estimates were prepared for the two closure alternatives that passed the initial screening process. While both alternatives included dewatering the pit and treating the water in a lime neutralization plant, one alternative consisted of treating the mine waste with a liming agent and filling the pit with the treated mine waste. The other alternative did not treat the mine waste, but consisted of placing the untreated tailings into an engineered landfill, to be located near the mine site and above the 100-year flood plain. Because of the mineralized condition of the rock adjacent to the pit, this second alternative assumed that the pit would need to be filled with limestone rock. Based on the fine screening evaluation, the alternative that included treatment of the mine waste and placing the treated mine waste in the pit was selected for implementation.

A Mine Site Characterization/Closure Plan and an Initial Study/Mitigated Negative Declaration were prepared and submitted for approval by the State of California Regional Water Quality Control Board-Central Region, the lead regulatory agency for this project. The project was approved in April 2001.

MINE CLOSURE IMPLEMENTATION

Reclamation activities began in April 2001. Initial reclamation activities included securing the site perimeter with fencing, installing temporary erosion and sediment controls such as silt fences and limestone berms, construction of access roads, and site grading for laydown areas and treatment plant facilities. The major activities associated with the mine reclamation are presented below.

Water Treatment Plant

The purpose of the Water Treatment Plant at the Spenceville Mine was to treat the approximately 6 million gallons of acid mine drainage accumulated in the old mine pit so that the mine could be reclaimed. Treated water from the plant was discharged to a nearby land area in a safe, passive application process that resulted in minimal impact to the area soils and vegetation. The approach used for water treatment and disposal is described below.

Pit Water Chemistry

One of the most common occurrences of acidic conditions in the environment is associated with the mining and exposure of coal seams and hard rock deposits containing base or precious metals. Pyrite occurs within the ore material due to the reducing conditions under which the metals were deposited. Mining operations expose the ore and associated sulfide minerals in the host rock to oxygen and moisture either in the underground workings or in the surface waste rock and tailings dumps.

The oxidation of pyrite under these oxidizing conditions is not a simple process, but may be generalized by the following reaction:

$$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_{3\ solid} + 8SO_4^{2-} + 16H^+ \qquad (1)$$

This reaction shows that in the presence of molecular oxygen, the iron (Fe) and sulfur (S) in the pyrite are oxidized by oxygen (O_2) to produce the stable iron solid, ferric hydroxide ($Fe(OH)_3$), and dissolved sulfate (SO_4^{2-}) and acid (hydrogen ions). The release of hydrogen with a strong acid anion (sulfate) results in acidic solutions unless other reactions occur to neutralize the acidity released by the oxidizing pyrite. As reaction (1) proceeds, solution pH decreases and the reaction propagates by:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (2)$$

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \qquad (3)$$

Presenting the reactions (2) and (3) in this form illustrates the importance of ferric iron (Fe^{3+}) as the primary oxidant of sulfide with oxygen serving as the primary oxidant of ferrous iron (Fe^{2+}). Also note that the oxidant ferric ion in solution is limited by the formation of ferric hydroxide ($Fe(OH)_3$). The formation of this solid also creates acidity via:

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3\ solid} + 3H^+ \qquad (4)$$

At the Spenceville Mine, acidity has been created by the oxidation of pyrite in the underground workings along with the oxidation of copper and zinc sulfide minerals in ore and waste piles. As a result of reactions (1) through (4), pit water and tailings pore water have very low pH values (high acidity) approaching 2.4 in many cases and very high copper and zinc concentrations. At the cessation of mining (early 1900s) the pit filled with water and became acidic and metal rich due to the exposed oxidizing pyrite and copper/zinc sulfide minerals.

Acid Mine Drainage accumulated in the pit at Spenceville Mine was previously characterized by Walker & Associates, et al in the Spenceville Mine Closure Plan (July 2000) as shown on Table 1.

The data demonstrated these important features of the mine pit water:

- The pit is highly stratified. The top 0 to 15 ft is relatively dilute compared to the deeper portions of the pit.
- Meteoric water and runoff tend to both mix and dilute only the upper few feet of the pit. Mixing and turnover with the lower 15 to 60 feet of water appear not to occur.
- Acidity, metals and most of the major cations and anions all increased in concentration with depth. Sulfate increased from about 1000 mg/L in the top 3 ft to almost 15000 mg/L near the bottom of the pit. Dissolved iron (total) ranged from 100 mg/L in the surface water to about 4000 mg/L at the pit bottom. Dissolved Fe in the lower portion of the pit is

entirely Fe (II) suggesting that reducing conditions prevail in the lower part of the mine pit.

Table 1 *Pit Water Chemistry (Mean of all Locations).*

		3' depth (1988)	**15' depth (1988)**	**45' depth (1988)**	**3' depth (2000)**	**15' depth (2000)**	**45' depth (2000)**
Ph	[std units]	2.7	2.2	2.6	2.8	2.4	2.7
Alk.	[mg/L]	0	0	0	0	0	0
Acid.	[mg/L]	750	3700	11000	590	2640	9120
SO_4	[mg/L]	1300	4800	14000	742	3800	12100
Cl	[mg/L]	2	<4	<4	<40	<40	<40
Na	[mg/L]	19	30	55	10.1	23.5	41.2
K	[mg/L]	nd	8.6	29	1.2	0.8	0.25
Ca	[mg/L]	120	220	430	106	221	365
Mg	[mg/L]	75	200	530	20	175	494
Cd	[mg/L]	0.09	0.15	0.31	0.029	0.058	0.240
Cu	[mg/L]	30	160	230	18.9	86	202
Pb	[mg/L]	nd	nd	nd	0.009	0.023	<0.003
Zn	[mg/L]	20	45	220	9.80	22.7	145
As	[mg/L]	na	na	na	0.0054	0.024	0.0037
Ni	[mg/L]	na	na	na	<0.100	0.234	0.884
Fe (II)	[mg/L]	na	na	4900	na	na	3900
Fe (total)	[mg/L]	120	910	4900	na	na	3860

Conceptual Plant Design

The main constituents of concern in the pit water were copper, zinc, iron, and acidity. Because the solubility of these metals decreases with increasing pH, addition of alkalinity to the pit water (neutralization) simultaneously raises the pH and causes the removal of metals from solution via precipitation.

The removal of zinc and copper in the mine water is similar to the removal of iron by formation of ferric hydroxide discussed earlier (equation 4):

$$Cu^{2+} + 2OH^{-} \rightarrow Cu(OH)_{2\ solid} \quad (5)$$

and

$$Zn^{2+} + 2OH^{-} \rightarrow Zn(OH)_{2\ solid} \quad (6)$$

or

$$Cu^{2+} \text{ (or Zinc)} + CO_3^{2-} \rightarrow CuCO_{3\ solid} \quad (7)$$

Thus raising the pH increases hydroxyl ions (OH^-) and carbonate or bicarbonate (CO_3 and HCO_3) allowing metals to form solids and precipitate out of solution and thereby improving water quality. The treatment plant at the Spenceville mine used this technique to remedy the cited constituents of concern in a single-phase neutralization process.

Plant Operation

Photos 4 and 5 show the pit in various stages of dewatering, and Photos 6 and 7 show the treatment plant during operation. Water from the pit was pumped at approximately 150 gallons per

Photo 4 - Mine pit dewatering, July 16, 2001

Photo 5 - Mine pit dewatering, July 26, 2001

minute into four 5,000-gallon reaction tanks from three pumps placed in the pit at 10, 25, and 45 feet below the water surface, respectively. The use of multiple pumps allowed blending of water to maintain consistent influent chemistry. Once in the plant, gravity flow was used to forward process water from one treatment unit to the next. In the first main reactor, an air line aerated the pit water to ensure that any ferrous iron existing under anaerobic conditions in the pit was converted to ferric iron, which is amenable to removal via neutralization. Neutralization in this reactor was achieved by the addition of hydrated lime slurry (30 % $Ca(OH)_2$) to pit water in the well-mixed, aerated tank. A pH controlled lime pump was used to maintain tank pH at approximately 7.5, which is the titration endpoint that provides minimum solubility of the constituents of concern.

Photo 6 - Treatment plant

Effluent from the main reactor tanks drained into a 1,000-gallon flocculation/coagulation tank. In this tank, polymer that aids in the solidification and formation of easily filterable flocs was added to the reaction slurry containing neutralized water and metal hydroxide solids. After addition of polymer in the flash mixing chamber occurred, the mixture entered the gently mixed main tank for coagulation.

Photo 7 - Treatment plant and pit dewatering

Coagulation tank effluent drained into an upright 5,000 gallon clarifier with removable lamella plates. In the clarifier, metal hydroxide solids settled and drained out the bottom. Clean, treated water overflowed out the top and was collected in a pH adjustment tank and then to a 500,000 gallon holding pond before being pumped to the land application area for discharge.

Sludge from the clarifier was pumped into a solids holding tank. Sludge slurry was pumped to two parallel filter presses, where it was dewatered. Effluent from the filter press was routed to the treated water holding tank and dewatered sludge was transported to a holding area on site before eventually being hauled to a licensed hazardous waste facility.

<u>Treatment plant effluent water quality</u>

Typical effluent water quality is presented in Table 2. Removal of the main constituents of concern (iron, copper, and zinc) as well as other trace constituents of concern (such as lead) was approximately 99%, as shown on Table 2.

Table 2. *Bench Scale Treatment Tests Using Hydrated Lime.*

		Initial composite pit water	Treated effluent	% Removal	Target Effluent Water Quality
pH	[std units]	2.54	7.0	-	6.5 to 9
Sulfate	[mg/L]	5547	3100	-	3100
Calcium	[mg/L]	231	1000	-	1000
Cadmium	[mg/L]	0.11	<0.05	-	0.005
Copper	[mg/L]	121	<0.1	>99.9	0.2
Iron	[mg/L]	853	9.3	98.9	<10
Magnesium	[mg/L]	229	170	0	<200
Manganese	[mg/L]	12	4.1	65.8	<5
Nickel	[mg/L]	1.0	<0.1	>90.0	0.1
Lead	[mg/L]	0.3	<0.005	>98.3	0.015
Zinc	[mg/L]	38	0.2	>99.5	2.0
Nitrate	[mg/L]	0.6	0.57	0	<10
Chloride	[mg/L]	4	3.8	0	<10

Mine Waste Excavation, Treatment, and Placement

Approximately 70,000 cubic yards (cy) of tailings were excavated and mixed with sugar beet lime to raise the pH. The treated tailings were placed in the pit and compacted to reduce their volume and compressibility.

Mine waste and mine-impacted materials at the site included the following:

- Hematite tailings: red-purple-black roasted ore material.
- Jarosite piles: piles of yellowish mine overburden material.
- Disturbed native materials: the areas mapped as containing “disturbed native materials” included three benches (flat areas) where various mine facilities were once located and the area to the east and south of the mine pit.
- Pit bottom sediments: mainly hematite mine waste that eroded from the hematite deposits and was transported into the pit by storm runoff.

Field batch testing was performed to determine the dosage of sugar beet waste lime required to neutralize each material. Based on these batch tests, the following minimum lime dosages were determined (weight of lime/weight of material):

- Hematite: 52 mg/g
- Jarosite: 274 mg/g
- Disturbed Native: 32 mg/g
- Pit bottom sediments: 78 mg/g

Initial access into the dewatered pit was via an excavated ramp on the east rim of the pit. The ramp was excavated about half way down to the pit bottom, at which point a temporary fill of lime treated mine waste and excavation rubble was placed from the bottom of the excavation to the floor of the pit (Photo 8). Prior to beginning excavation of the pit bottom sediments, a large crane with a clamshell bucket was mobilized to remove several vehicles and other debris that were found at the bottom of the pit. After removal of the debris, excavation and treatment of pit bottom sediments began the first week of August 2001. While excavating the pit bottom sediments, the depth to a hard rock bottom was found to be significantly deeper than originally anticipated. Several test pits were dug into the pit sediments to determine the characteristics and estimate the depth of material in the bottom of the pit. Each test pit exposed a layer of hematite mine waste and/or fill material used for construction of the pit ramp, overlying a deposit of non-reactive metavolcanic rubble of undetermined depth. To address the unanticipated thick deposit of rubble on the pit floor, the pit bottom sediments were removed and the upper two feet of coarse rubble material were replaced with a two-foot-thick layer of compacted crushed limestone (Photo 9). The crushed limestone layer provided a base for placing the treated mine waste, and provided buffering for potential migration of acidic water into the pit.

Photo 8 - Pit access ramp

Photo 9 - Pit bottom stabilization with limestone

After treatment of the pit bottom sediments, placement of treated mine waste began. A conveyor system was set up for conveying the mine waste and lime into the pit (Photo 10). The conveyor system consisted of two sets of traps, motors and conveyors, one for the mine waste and the other for the lime. The two conveyors discharged onto a main conveyor, which transported the mixed mine waste and lime into the pit. A water spray nozzle was located at the end of the main conveyor to minimize dust generation as the material dropped into the pit. The speed of each conveyor was calibrated to obtain the proper lime dosage for each material. The lime and mine waste were further mixed at the bottom of the pit by dozers. The dozers spread the treated mine waste in 8-inch to one-foot lifts, and each lift was compacted with a sheepsfoot roller. Treated mine waste was compacted to 95% of the maximum dry density as determined by ASTM D698. Once the elevation of the treated mine waste in the pit approached the elevation of the pit rim, the conveyor system was removed and the mine waste and lime were placed, mixed and spread in the pit with dump trucks and dozers (Photo 11). Since the volume of material placed in the pit exceeded the capacity of the pit, a mound of treated mine waste was constructed over the pit. After all the treated mine waste was placed, the side slopes of the mine waste pile were armored with riprap to protect the pile from erosion by Little Dry Creek and Dry Creek flood waters.

Photo 10 - Mine waste placement with conveyor

Quality control measures were implemented to provide a high level of confidence that the excavation, treatment and compaction of mine waste materials were satisfactorily completed. Quality control measure's included the following activities:

- In place density tests for compaction verification. Both sand cone and nuclear gage density tests were performed.
- In place dosage testing of the treated mine waste.
- Excavation of confirmatory test pits in excavated areas to confirm mine waste removal.

Photo 11 - Mine waste placement with trucks and dozers

Photo 12 - Post-excavation grading

After the mine waste was excavated, and prior to placement of soil cover, the slopes of the excavated surfaces were regraded locally. The slopes were graded to 3 horizontal to 1 vertical (3H:1V) or flatter to reduce erosion, facilitate revegetation, and smoothly merge the topography of the regraded site with the adjacent land. In steep areas, or areas which had an abrupt change in topography, clean fill from a borrow area was placed to flatten the slopes and provide a smooth topographic transition (Photo 12).

Reclamation of Shafts and Tunnels

Dewatering of the pit revealed several old adits and a shaft within the pit (Photo 13). It was determined that a mixture of 60 % limestone and 40% fresh bentonite (by volume) would be used to stabilize the adits and shaft. The purpose of the bentonite was to minimize seepage of potentially acid water into the pit, while the purpose of the limestone was to buffer any seepage that does move into the pit.

The limestone/bentonite material was placed into each adit as deep as possible with an excavator bucket. The shaft was filled with quarry rock to about 20 feet below the rim of the shaft. The remainder of the shaft was filled with the 60/40 mix of limestone and bentonite. After remediation, the adits and shaft were buried with placement of the treated mine waste in the pit.

Photo 13 - Shaft and adit in mine pit

Site Grading and Placement of Soil Cover

After initial site grading, and prior to placing clean soil cover, the excavated mine site subgrade was amended with 10 tons of sugar beet lime per acre, 67 cubic yards per acre of compost, and 100 pounds per acre of fertilizer. A soil cover borrow area was developed off-site to provide soil for revegetating the mine. Prior to excavation of cover soil from the borrow area, the top 6 to 8 inches of topsoil were stripped and stockpiled for later use in reclaiming the borrow area. The cover soil was loaded and transported to the mine site using wheel-scrapers with a capacity of about 20 cy. The cover soil was spread at the mine site by dozers to the specified thickness, which was two-feet thick over the treated mine waste pile and the footprint of the former tailings piles, and one-foot thick in the areas which had disturbed native material (Photo 14).

Photo 14 - Placement of soil cover

After placement, the cover soil was amended with 134 cubic yards per acre of compost and 100 pounds per acre of fertilizer. After amendment with fertilizer and compost, a wood chip mulch layer was placed over the cover soil to control erosion, help prevent the establishment of weed species and conserve soil moisture.

The borrow areas were reclaimed by grading the areas to blend in with the adjacent undisturbed contours and by amending and spreading the stockpiled topsoil over the graded substrate.

Stream Restoration

Little Dry Creek received run-off leachate from the waste piles and overflow of water from the mine pit, resulting in significant loading of metals and acidic water to the stream. Although the affected area appeared to be mainly restricted to the section of Little Dry Creek adjacent to the mine site, both these factors decreased the suitability of the creek as habitat for aquatic receptors. In addition, Little Dry Creek near the mine site had a hard-bottom substrate of cemented rocks, very little overlying sediment, virtually no submerged aquatic vegetation, and very shallow water in most places. This combination of features contributed to the creek offering poor quality habitat for aquatic species.

Based on a review of pre-mining site photos and a survey of the existing creek bed area, it was determined that the original pre-mining stream channel was east of the existing channel. Stream restoration thus included re-establishing the original stream channel. The construction work involved grading the stream and clearing the old channel before diversion barriers were removed to divert stream flows from the existing channel to the new channel. The altered streambed contains ponds, swales and large rocks to produce well-aerated water with numerous areas for establishment of pre-mining creek habitat (Photo 15). Re-colonization by benthic invertebrates from upstream locations following re-establishment of normal creek flow should result in re-population of the creek with a similar abundance and diversity of benthic organisms as present before mining occurred.

Photo 15 - Relocated Little Dry Creek

Prior to excavation of the new channel, the existing channel of Little Dry Creek adjacent to the mine site was temporarily diverted as part of the remedial work to permit removal of iron and aluminum hydroxide sediments and evaporative salts from the creek bed. Removal was performed by washing the creek bed with high-pressure water jets. After cleaning and excavation of the new channel, the old channel was filled with clean fill and lime rock to ensure neutralization of seeps in the channel and to provide a good growth medium for new vegetation.

As part of the investigation being conducted at this site in support of the remediation, benthic invertebrate samples were collected from multiple locations upstream and downstream of the mine site on Little Dry Creek and Dry Creek prior to the start of remedial activities. Invertebrate abundance and diversity were measured in these samples. Following completion of remediation activities, and after sufficient time has passed to allow for re-colonization, these areas will be re-sampled for invertebrate abundance and diversity. Comparison of pre- and post-remedial survey results will permit evaluation of the effectiveness of remediation and its impact on the benthic fauna of the stream.

Site Revegetation

A revegetation plan was developed to provide a sustainable, erosion resistant vegetative cover using site-adapted species. Distinct planting zones were created for the relatively steep upper mine slopes, relatively flat lower benches (adjacent to Little Dry Creek) and the graded mine waste pile in order to foster a diversity of plant communities and wildlife habitats throughout the site, and to provide an erosion resistant vegetative cover in areas with varying slopes, landscape position, etc. The plants that will be utilized in the revegetation program are summarized in Table 3.

All species listed were chosen for their adaptability to the site, or for their erosion control or wildlife habitat potential. All native grass and forb seed used for this project will originate from northern California seed accessions. Seeds for the native tree and shrub species were obtained from areas adjacent to the mine site and are being grown as containerized seedlings.

Table 3. *Summary of Plants for Site Revegetation*

Planting Zone	Plant Type	Plant Common Name
Upper Mine Slopes	Trees and Shrubs	Foothill pine, Blue oak, Interior live oak, California buckeye, Redbud, Buckbrush, Coyote bush
	Native Grasses	Purple needlegrass, Blue wildrye, California oniongrass, Creeping wildrye
Lower Mine Benches	Trees and Shrubs	Blue oak, Interior live oak, California buckeye, Redbud, Coyote bush, Willow
	Native Grasses	Purple needlegrass, Nodding needlegrass, Creeping wildrye, Pine bluegrass, Blue wildrye, Squirreltail, California oniongrass, Deergrass
	Native forb seeds	Yarrow, Small-flowered lupine, California poppy, Spanish clover
Mine Waste Pile	Native Grasses	Purple needlegrass, Nodding needlegrass, Creeping wildrye, Pine bluegrass, Blue wildrye, Squirreltail, California oniongrass
	Native forb seeds	Yarrow, Small-flowered lupine, California poppy, Spanish clover

The riparian zone along Little Dry Creek was revegetated after stream relocation in December and January 2002. The remainder of the mine site will be revegetated in the Fall of 2002. It is anticipated that hand watering of the plants will be required when they are planted in the Fall of 2002, and during the dry season in 2003 (April – September) until the trees and shrubs have been established. Additionally, weeds will be controlled for several years following revegetation by hand pulling as well as the use of herbicides.

Archaeological Investigations

Archaeological investigations were conducted from June 2001 to November 2001 (Photo 16). These investigations revealed eighteen historical features or elements of features. Archaeological findings included a 126 foot by 30 foot concrete platform, which apparently was used to dry copper cement with associated strap rail system to move the material, and a subterranean tar and felt covered wooden containment tank, 24 feet long by 12 feet wide, with canvas gaskets designed to be placed between wallboards and uprights. The most striking finds were made during mine waste excavation. A wooden conduit was discovered beneath tailings exceeding 25 feet in depth. The conduit was 134 feet long on a 10 percent grade with an internal channel that narrowed from 6 inches wide to 4 inches wide. Also, a tar covered brick

Photo 16 - Archaeological investigations during excavation

settling tank and a tar-coated canvas covered wooden tank were discovered beneath tailings of 14 to 16 feet in depth. The mine pit proper revealed an incline on the southwest wall with only strap rails missing, and a partially timbered vertical shaft was discovered in the west wall. Two ore buckets were recovered both with wooden trap doors in the base and one bucket has remnants of tar lining the inside. Overseas Chinese porcelain and stoneware shards were found near some refractory ovens.

Methodologies used in field exploration at the mine were varied and appropriate to the conditions. The concrete platform was one of only two features where simple archaeological tools were used. During removal of the extensive tailings heavy equipment was the initial choice. The equipment was used to locate historic surfaces at which point excavators used traditional archaeological tools. Artifacts that were revealed were bagged and tagged for future processing. All work was photographically recorded as were features and artifacts.

Unexploded Ordnances

As discussed above, from 1941to1962 the Spenceville Mine area was under the jurisdiction of the US Army. Information received from the US Army Corps of Engineers indicated that there was a potential for unexploded ordnances (UXO) and chemical warfare material (CWM) at the site and, specifically, that one of the areas proposed as a borrow source for clean soil cover was used as a bomb test range. Based on this information, a UXO and CWM specialty contractor was retained to provide UXO and CWM construction support.

Initial site activities included a records search at the adjacent Beale Air Force Base, UXO and CWM training to onsite personnel, a visual reconnaissance of the mine site area, and geophysical surveys of the borrow areas. Information obtained from Beale Air Force base described ordnance removal actions in 1947 and 1964 in the mine site vicinity, which, at the time, resulted in the discovery of many live UXO items; the live UXO items were removed upon discovery. Results of the geophysical survey and visual reconnaissance yielded about 14 ordnance related items, primarily scrap from 81mm and 60mm mortars. No live ordnances were discovered.

Photo 17 - Vehicles at bottom of pit

Subsequent activities addressed the potential for UXO and CWM in the mine pit, and the possibility of uncovering UXO during excavation of cover soil from the borrow areas. After the pit was dewatered, a visual and geophysical inspection of the pit bottom was conducted (Photo 17). UXO support continued during excavation and treatment of the pit bottom sediments, and during stripping of the borrow areas for cover soil. While several ordnance related items were retrieved, including an M-1 clip, M-4 105 shell casing, parachutes, and a site tube from gas tanks, no live ordnances or CWM were discovered.

SUMMARY

The Spenceville Mine Closure proceeded on schedule and, as of July 2002, is nearly finished (Photo 18). The only remaining portions of the closure are the drilling of two down-gradient groundwater monitoring wells, and revegetation of a portion of the site. In all, the project was completed in about 18 months and accomplished the following:

Photo 18 - Final site grading – note that filled mine pit is in center of photo

- The mine pit was drained in 8 weeks and treated water was used to irrigate nearby fields.
- The pit was backfilled with neutralized mine waste and then covered with clean fill. The shafts and adits were also treated and filled to minimize seepage.
- The site was contoured to fit pre-mining contours and much of the area has already been revegetated.
- The nearby stream, Little Dry Creek, was moved to its original location and stream habitat restored. Seeps and overflow from the flooded mine pit were eliminated.
- Intensive archaeological studies unearthed old mining structures and sites of cultural interest that were catalogued and preserved for future access.
- Surface water and groundwater have been restored to near pre-mining conditions. Both will be monitored for many years.

The Spenceville Mine site has been returned to usable open space consistent with the intent of the wildlife refuge.

REFERENCES

Walker & Associates and GEI Consultants, Inc., July 2000, *Mine Site Characterization/Closure Plan*, Spenceville Mine Site, Nevada County, California.